OPTIONS FOR ALLOCATING THE PRECAUTIONARY CATCH LIMIT OF KRILL AMONG SMALL-SCALE MANAGEMENT UNITS IN THE SCOTIA SEA

R.P. Hewitt✉
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037, USA
Email – roger.hewitt@noaa.gov

G. Watters
Pacific Fisheries Environmental Laboratory
352 Lighthouse Avenue
Pacific Grove, CA 93950-2097, USA

P.N. Trathan
British Antarctic Survey
Natural Environment Research Council
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

J.P. Croxall
British Antarctic Survey
Natural Environment Research Council
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

M.E. Goebel
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037, USA

D. Ramm
CCAMLR Secretariat
PO Box 213, North Hobart 7002
Tasmania, Australia

K. Reid
British Antarctic Survey
Natural Environment Research Council
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

W.Z. Trivelpiece
Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92037, USA

J.L. Watkins
British Antarctic Survey
Natural Environment Research Council
High Cross, Madingley Road
Cambridge CB3 0ET, United Kingdom

Abstract

Following an assessment of Antarctic krill (*Euphausia superba*) in the Scotia Sea, CCAMLR established a precautionary catch limit of 4 million tonnes and further adopted 15 small-scale management units (SSMUs). The intent was to subdivide the precautionary catch limit for krill among the SSMUs so as to preclude the inadvertent concentration of catches in a small portion of the surveyed area. Five options for allocating the catch limit among the SSMUs in the Scotia Sea are presented in this paper. The first four are static allocations where the allotment of catch to an SSMU is proportional to: (i) the historical catch within the SSMU; (ii) estimated predator demand in the SSMU; (iii) estimated standing stock of krill in the SSMU; and (iv) standing stock less predator demand in the SSMU. The fifth option is a dynamic allocation based on land-based predator monitoring conducted just prior to, or early in, the fishing season. For the purposes of illustration and comparison between the options, parameter estimates are made using available data, although it is recognised that considerable refinement of these estimates is possible. Qualitative conclusions are that: under the first two options a substantial portion (>65%) of the catch limit would be allocated to three or less of the SSMUs adjacent to large concentrations of land-breeding predators; under options (iii) and (iv) a similar portion of the catch limit would be directed to pelagic SSMUs beyond the foraging range of these predators but into areas where krill fishing has not regularly occurred; and under option (v), an example of an adjustable catch limit dependent on the results of ecosystem monitoring, the fishery would be restricted in some of its traditional fishing grounds during years of low krill availability. Under all five options there would be little effect on the existing fishery. However, as catches increase, a trade-off may be drawn between options that displace the fishery from its current operating area, but reduce the potential for contravening the terms of the Convention, and options that do not displace the fishery, but are likely to contravene the terms of the CCAMLR Convention.

Résumé

Suite à une évaluation du krill antarctique (*Euphausia superba*) dans la mer du Scotia, la CCAMLR a établi une limite de capture de précaution de 4 millions de tonnes et a ensuite adopté 15 unités de gestion à petite échelle (SSMU). L'intention était de subdiviser la limite de capture de précaution de krill entre les SSMU de manière à empêcher la concentration involontaire des captures dans une partie restreinte de la zone d'étude. Ce document présente cinq possibilités d'allocation de la limite de capture aux SSMU de la mer du Scotia. Les quatre premières sont des allocations statiques où l'attribution de la capture à une SSMU est proportionnelle à : (i) l'ancienne capture dans la SSMU; (ii) l'estimation des besoins des prédateurs dans la SSMU; (iii) l'estimation du stock existant de krill dans la SSMU; et (iv) la différence entre le stock existant et les besoins des prédateurs dans la SSMU. La cinquième possibilité est une allocation dynamique fondée sur un contrôle des prédateurs terrestres réalisé juste avant ou au tout début de la saison de pêche. Pour des besoins illustratifs et comparatifs entre les diverses possibilités, les estimations paramétriques sont effectuées à partir des données disponibles, tout en reconnaissant que ces estimations peuvent être considérablement améliorées. Les conclusions qualitatives sont que : dans les deux premiers cas, une portion importante (>65%) de la limite de capture serait allouée à un maximum de trois SSMU adjacentes aux vastes concentrations de prédateurs se reproduisant à terre; dans le cadre des possibilités (iii) et (iv) une portion aussi importante de la limite de capture serait attribuée aux SSMU pélagiques situées au-delà du secteur d'alimentation de ces prédateurs, mais dans des secteurs où la pêche au krill n'a jamais été régulière; concernant la dernière possibilité (v), exemple d'une limite de capture ajustable, dépendante des résultats d'un contrôle de l'écosystème, la pêche serait restreinte dans certains de ses lieux de pêche traditionnels les années pauvres en krill. Aucune de ces solutions n'affecterait considérablement la pêche actuelle. Toutefois, au fur et à mesure que les captures augmenteront, il conviendra d'établir un compromis entre celles qui éloignent la pêche de son secteur d'opération actuel, mais qui réduisent la possibilité d'infraction aux termes de la Convention, et celles qui, sans déplacer la pêche, sont susceptibles d'aller à l'encontre des termes de la Convention de la CCAMLR.

Резюме

В результате оценки антарктического криля (*Euphausia superba*) в море Скотия АНТКОМ установил предохранительное ограничение на вылов на уровне 4 млн. т и затем принял 15 мелкомасштабных единиц управления (SSMU). Целью было подразделение предохранительного ограничения на вылов криля между SSMU с тем, чтобы предотвратить случайную концентрацию уловов в небольшой части обследованного района. В этой статье рассматриваются пять вариантов распределения ограничения на вылов между SSMU моря Скотия. Первые четыре представляют собой статическое распределение, где уровень вылова в SSMU пропорционален: (i) историческому вылову в этом SSMU; (ii) оценочным потребностям хищников в этом SSMU; (iii) оценочной биомассе запаса криля в этом SSMU; и (iv) биомассе запаса за вычетом потребностей хищников в этом SSMU. Пятый вариант – это динамическое распределение, основанное на мониторинге наземных хищников, проведенном непосредственно перед или в начале промыслового сезона. В целях объяснения и сравнения этих вариантов по имеющимся данным были выполнены оценки параметров, хотя надо отметить, что возможно значительное улучшение этих оценок. Делаются следующие качественные выводы: при первых двух вариантах значительная часть (>65%) ограничения на вылов будет приходиться на три или менее SSMU, примыкающих к большим скоплениям размножающихся на суше хищников; в соответствии с вариантами (iii) и (iv) аналогичная доля ограничения на вылов будет приходиться на пелагические SSMU за пределами ареала кормодобывания этих хищников, но в районах, где промысел криля не ведется регулярно; и в соответствии с вариантом (v) (пример регулируемого ограничения на вылов, зависящего от результатов экосистемного мониторинга) промысел будет ограничен на некоторых традиционных промысловых участках в годы низкого наличия криля. Любой из этих пяти вариантов мало скажется на существующем промысле. Однако при увеличении уловов может потребоваться компромисс между вариантами, которые вытесняют промысел из существующих районов его ведения, но сокращают возможность нарушения условий Конвенции, и вариантами, которые не вытесняют промысел, но могут привести к нарушению условий Конвенции АНТКОМ.

Resumen

Tras una evaluación del kril antártico (*Euphausia superba*) en el mar de Escocia, la CCRVMA estableció un límite de captura precautorio de 4 millones de toneladas y adoptó 15 unidades de ordenación en pequeña escala (UOPE). La subdivisión del límite de captura precautorio de kril entre las UOPE se hizo con el objeto de evitar que la explotación se concentrara inadvertidamente en una pequeña sección del área prospectada. Este trabajo presenta cinco opciones para distribuir el límite de captura entre las UOPE del mar de Escocia. Las primeras cuatro opciones representan una asignación estática de una cuota de captura que es proporcional a: (i) la captura histórica dentro de la UOPE; (ii) la estimación de la demanda de los depredadores en la UOPE; (iii) una estimación de la biomasa instantánea de kril en la UOPE: (iv) la biomasa instantánea menos la demanda de los depredadores en la UOPE. La quinta opción representa una asignación dinámica basada en el seguimiento de los depredadores con colonias en tierra. Dicho seguimiento fue efectuado justo antes de la temporada de pesca, o bien a principios de la misma. Se han efectuado estimaciones de los parámetros con los datos disponibles a título ilustrativo y comparativo entre las opciones, si bien se reconoce que estos parámetros pueden ser refinados considerablemente. Los resultados de un análisis cualitativo indican que bajo las primeras dos opciones una parte substancial del límite de captura (>65%) puede ser asignado a tres, o menos, de las UOPE adyacentes a las mayores concentraciones de depredadores terrestres; bajo las opciones (iii) y (iv) una porción similar del límite de captura se dirigiría a las UOPE pelágicas situadas fuera del radio de alimentación de estos depredadores pero en áreas donde la pesca de kril no ha ocurrido con frecuencia; y de acuerdo con la opción (v), que es un ejemplo de un límite de captura ajustable según los resultados del seguimiento del ecosistema, la pesquería estaría restringida en algunos de sus caladeros de pesca tradicionales durante los años de baja disponibilidad de kril. Ninguna de las cinco opciones afectaría mayormente a la pesca de kril existente. No obstante, a medida que aumenten las capturas, se podría alcanzar un equilibrio entre las opciones que desplazan la pesquería de la zona donde opera actualmente, pero reducen la posibilidad de contravenir el mandato de la Convención, y las opciones que no desplazan la pesquería pero tienen una mayor probabilidad de contravenir dicho mandato.

Keywords: Antarctic krill, management, small-scale management units, precautionary catch limit, CCAMLR

Introduction

Following a multi-nation, multi-ship survey across the Scotia Sea in January–February 2000, the biomass of Antarctic krill (*Euphausia superba*) was estimated to be 44.3 million tonnes and a new precautionary catch limit of 4.0 million tonnes was adopted by CCAMLR for FAO Statistical Area 48 (CCAMLR, 2000) (for a description of the CCAMLR-2000 Survey see SC-CAMLR, 2000 and Hewitt et al., 2002). The Commission further subdivided the catch limit among Subareas 48.1 (1.008 million tonnes), 48.2 (1.104 million tonnes), 48.3 (1.056 million tonnes) and 48.4 (0.832 million tonnes) in order to distribute fishing effort and thereby reduce the potential impact of fishing on land-based predators. However, the Commission remained concerned that localised depletion of the krill resource could occur if all the catch was taken within a small proportion of a subarea and required that the total catch in Area 48 should not

Table 1: Designation, area (A_i), krill biomass density (ρ_i), and aggregate catch (C_i) (1988–2002) for each of the SSMUs adopted by CCAMLR in 2002. Estimates of krill biomass density (ρ) are from the results of the CCAMLR-2000 Survey as described in the text. Catch data are aggregated from submissions to the CCAMLR Secretariat and used here with the permission of the original submitters of the data.

SSMU	A_i (x10^3 km^2)	ρ_i (g m^{-2})	C_i (tonnes)
Antarctic Peninsula Pelagic Area (APPA)	483.4	11.2	25 376
Antarctic Peninsula West (APW)	36.7	37.7	7 400
Drake Passage West (APDPW)	15.8	37.7	227 741
Drake Passage East (APDPE)	16.4	37.7	103 169
Bransfield Strait West (APBSW)	22.0	37.7	11 463
Bransfield Strait East (APBSE)	28.7	37.7	5 952
Elephant Island (APEI)	36.2	37.7	94 930
Antarctic Peninsula East (APE)	61.6	37.7	25
South Orkney Pelagic Area (SOPA)	808.8	24.5	6 248
South Orkney West (SOW)	16.1	150.4	217 374
South Orkney North East (SONE)	10.8	150.4	15 856
South Orkney South East (SOSE)	15.5	150.4	19 531
South Georgia Pelagic Area (SGPA)	927.4	24.5	7 822
South Georgia West (SGW)	42.8	39.3	31 436
South Georgia East (SGE)	55.2	39.3	208 870

exceed 620 000 tonnes until the precautionary catch limit had been subdivided into small-scale management units (SSMUs). The Commission further directed the Scientific Committee to provide advice on the establishment of SSMUs for the krill fishery and on the spatial and temporal detail of information required from the krill fishery.

The Working Group on Ecosystem Monitoring and Management (WG-EMM) considered proposals for establishing SSMUs and elected to define 'predator units' based on considerations of land-based predator foraging ranges, krill distribution and the behaviour of krill fishing vessels (Constable and Nicol, 2002). This approach was endorsed by the Scientific Committee and the Commission (SC-CAMLR, 2001; CCAMLR, 2001), and a workshop was convened under the auspices of WG-EMM to define SSMUs in Area 48. The recommendations of the workshop were endorsed by the Scientific Committee (SC-CAMLR, 2002) and adopted by the Commission, which then directed the Scientific Committee to provide advice on how the precautionary catch limit for krill in Area 48 could be subdivided among the SSMUs (CCAMLR, 2002). The Commission also adopted a requirement that krill catches be reported at a scale of 10 by 10 n mile squares by 10-day periods at the end of the fishing season. In making this recommendation, the Scientific Committee noted that this requirement should be considered an interim measure and that haul-by-haul data by 10-day periods should be required when the precautionary catch limit is subdivided among SSMUs.

In this paper, five options are considered for subdividing the precautionary catch limit for krill in Area 48 among the SSMUs adopted by the Commission. The aim here is to stimulate discussion on general approaches rather than advocate specific proposals.

Four of the options may be considered static allocations: the first is proportional to the historical catch in each SSMU; the second is proportional to estimated predator demand in each SSMU; the third is proportional to the estimated standing stock of krill in each SSMU; and the fourth is proportional to the standing stock less predator demand in each SSMU. The fifth option is a dynamic allocation based on land-based predator monitoring conducted just prior to or early in the fishing season. The SSMUs adopted for Subareas 48.1, 48.2 and 48.3 are described in Figure 1 and Table 1. Because SSMUs were not defined for Subarea 48.4, the portion of the precautionary catch limit for krill allocated to this subarea is not considered here.

Options

Each option takes the general form $Y_i = Ya_i$, where Y_i is the precautionary catch limit in the ith SSMU; a_i is the fraction of the total precautionary catch limit (Y) that can be taken in the ith SSMU; and $\Sigma a_i = 1$. A large number of possible options could be described (see for example Watters and Hewitt, 1992), where a trade-off was made between options that were biologically explicit but required delayed implementation and those options that

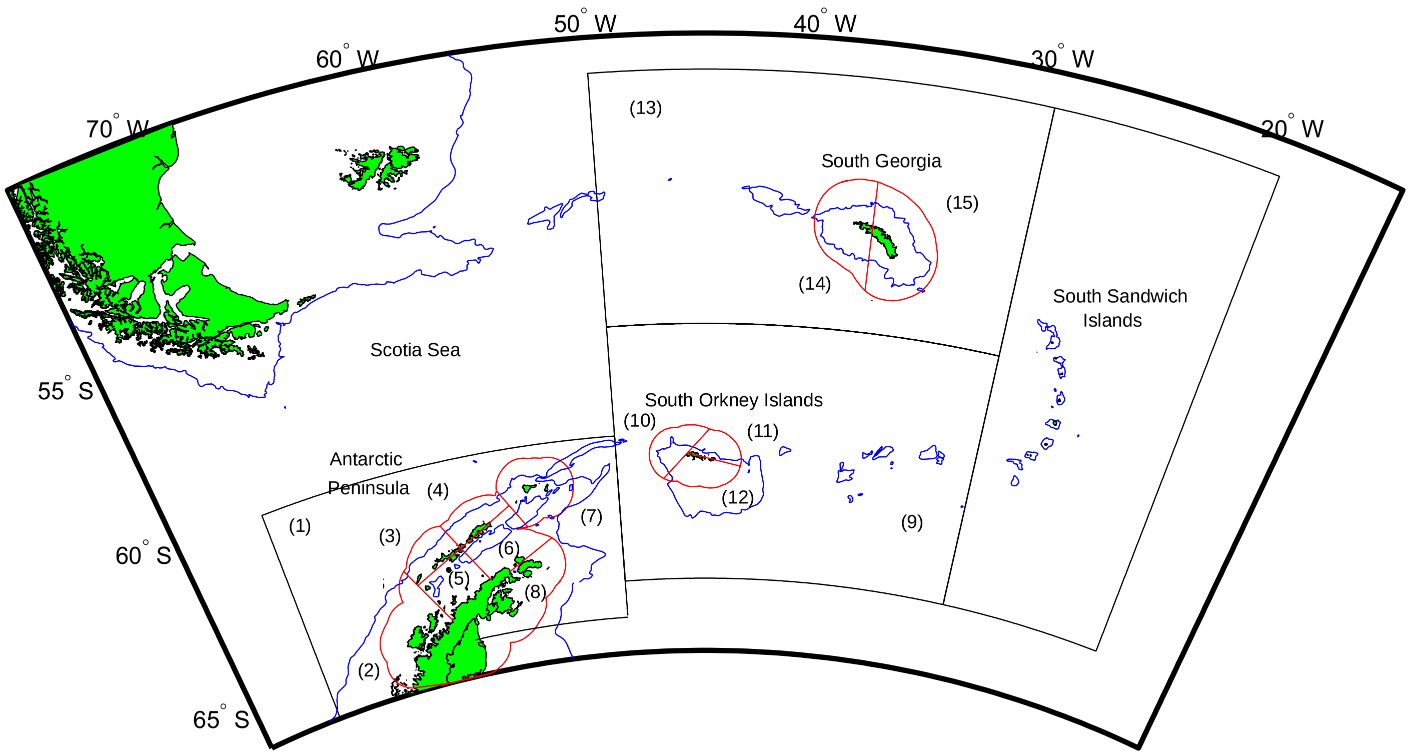

Figure 1: Small-scale management units (SSMUs) in Subareas 48.1, 48.2 and 4.3. The 1 000 m isobath is also shown to indicate the approximate edge of the continental shelf surrounding the archipelagos in the Scotia Sea. SSMUs are: (1) Antarctic Peninsula Pelagic Area (APPA); (2) Antarctic Peninsula West (APW); (3) Drake Passage West (APDPW); (4) Drake Passage East (APDPE); (5) Bransfield Strait West (APBSW); (6) Bransfield Strait East (APBSE); (7) Elephant Island (APEI); (8) Antarctic Peninsula East (APE); (9) South Orkney Pelagic Area (SOPA); (10) South Orkney West (SOW); (11) South Orkney North East (SONE); (12) South Orkney South East (SOSE); (13) South Georgia Pelagic Area (SGPA); (14) South Georgia West (SGW); (15) South Georgia East (SGE). Note that SSRU APE extends partly into Subarea 48.5.

were biologically unrealistic but could be implemented immediately). However, this study focused on five alternatives: four static options, and one dynamic option that could be implemented immediately with the limited information to hand, and improved as new information became available.

Given the limited knowledge of the system, several fundamental assumptions were necessary: (i) harvesting methods will remain the same as those currently employed; (ii) mitigation measures to reduce fishery by-catch are adequate; (iii) the current seasonal and geographic pattern of catches remains the same; (iv) transport of krill between SSMUs remains constant; and (v) climate-induced changes to the ecosystem are negligible.

The first option is that the catch limit in an SSMU be proportional to the total catches in that SSMU. This option is based on the premise that the distribution of fishing effort is affected only by the availability of krill and that where krill catches are highest, so is krill availability. This premise may not be entirely true if the fishery operates in areas with predictable aggregations rather than highest availability; or if fishing areas are limited by the knowledge of fishing masters, or by logistic or operational constraints. Furthermore, as the fishery develops, the total catches and their geographic distribution may change. As a first approximation, however, the distribution of catches among the SSMUs was taken as an indication of the distribution of krill. Thus, $a_i = C_i / \Sigma C_i$, where C_i is the total krill catch in the ith SSMU.

The second option is that the catch limit in an SSMU be proportional to the combined annual predator demand. It is based on the premise that the ecosystem is reasonably efficient and that high demand implies a high standing stock of krill, a high turnover rate, or both. This premise may not be entirely true if predators change their diets from krill to another prey. In this regard, preferences and prey switching are poorly understood for several presumed krill predator species. Furthermore, information is incomplete with regard to population estimates for major land-based krill predators, the distribution of pelagic krill predators, seasonal variations in foraging behaviour and diets, and energetic budgets. As a first approximation, considerations of predator demand were limited to Adélie, chinstrap, gentoo and macaroni penguins, lactating female Antarctic fur seals, baleen whales and fish; major consumer groups not included were male fur seals, flying seabirds, crabeater seals and squid. Thus, $a_i = \Sigma d_{ij}/\Sigma\Sigma d_{ij}$, where Σd_i is the demand in the ith SSMU summed over j predator species.

The third option is that the catch limit in an SSMU be proportional to the standing stock of krill. It is based on the premise that, in all areas where krill occurs, emigration balances immigration and that high biomass densities imply high availability. This premise may not be entirely true if the surveys used to estimate the standing stock of krill do not represent its distribution throughout the year, or between years. Furthermore, estimates of standing stock do not include information regarding the aggregation of krill on a scale important to fishing operations or availability to krill predators. As a first approximation, however, data generated from the CCAMLR-2000 Survey were used to indicate the distribution of krill among SSMUs. Thus, $a_i = \rho_i A_i/\Sigma\rho_i A_i$, where ρ_i and A_i are the density and area of the ith SSMU.

The fourth option is that the catch limit in an SSMU be proportional to the standing stock of krill less the annual predator demand. It is based on the premise that the amount of krill allocated to the fishery should be determined after accounting for predator demand; if the estimate of standing stock less predator demand for an SSMU is less than zero, then no catch limit would be allowed. Reservations similar to those expressed for the second and third options hold here. In addition, this option is based on the assumption that krill turnover is constant between SSMUs, and that the standing stock relative to predator demand is indicative of krill that may be available to the fishery in a given SSMU. Nevertheless, these estimates were used to generate a first approximation of how the catch may be distributed among SSMUs after considering both the standing stock of krill and predator demand. Thus, $a_i = (\rho_i A_i - \Sigma d_{ij})/(\Sigma\Sigma d_{ij} - \Sigma\rho_i A_i)$ and $a_i = 0$ if $\rho_i A_i - \Sigma d_{ij} < 0$.

The fifth option is that the catch limit in an SSMU be an adjustable proportion dependent on the value of an ecosystem monitoring index or some combination of indices. It is based on the premise that krill availability in an SSMU may change from year to year and that an index may have some predictive value in estimating krill availability. This may be particularly pertinent to the SSMUs near South Georgia, where predator reproductive success has a large dynamic range associated with large changes in krill availability (Croxall et al., 1999; Boyd and Murray, 2001). While it may be preferable to index krill biomass and/or hydrographic processes known to affect the transport and retention of krill in an SSMU, no standard methods for doing so have been defined or implemented. Alternatively, a_i may be defined as a function of a predator index reflecting early season availability of krill (e.g. arrival weights, egg mass, natality rate, foraging trip duration).

Data sources and parameter estimates

As no SSMUs for Subarea 48.4 have been adopted by the Commission to date, this study is confined to Subareas 48.1, 48.2 and 48.3. Accordingly, the precautionary yield for Area 48 has been reduced by the amount that the Commission allocated to Subarea 48.4. Thus $Y = (4.00 - 0.83) = 3.17$ million tonnes.

The distribution of krill catches among SSMUs was determined from data submitted to the CCAMLR Secretariat and aggregated over 10 by 10 n mile squares and one-month periods, representing over 95% of the krill harvested between 1993 and 2002. This period was chosen because total catch and behaviour of the fishing fleet have been relatively stable since 1992 when the catch dropped dramatically from ca. 500 000 tonnes per year to ca. 100 000 tonnes per year. These data are listed in Table 1.

Estimates of land-based predator demand were limited to that of Adélie, chinstrap, gentoo and macaroni penguins and lactating female Antarctic fur seals; consumption by male fur seals and flying seabirds was not included. Estimates of consumption by penguins and fur seals in the South Shetland Islands were taken from Croll and Tershy (1998). For penguins, consumption was divided among the six non-pelagic SSMUs in the South Shetland Islands in proportion to their area. For lactating fur seals, 91% of the consumption was apportioned to the Drake Passage West (APDPW) SSMU, 2% to the Drake Passage East (APDPE) SSMU and 7% to the Elephant Island (APEI) SSMU according to the distribution of fur seals among breeding colonies reported by Goebel et al. (2003). Consumption estimates for penguins at the South Orkney Islands were determined from abundances of breeding pairs reported by Woehler (1993) and consumption algorithms described by Croll and Tershy (1998). Penguin consumption in Subarea 48.2 was apportioned as follows: 5% to the South Orkney West (SOW) SSMU, 6% to the South Orkney North East (SONE) SSMU and 89% to the South Orkney South East (SOSE) SSMU following the distribution of colonies reported by Woehler (1993). There are no known breeding colonies of fur seals in the South Orkney Islands. Macaroni penguin consumption estimates for South Georgia were taken from Boyd (2002), and of these, 96% was apportioned to the South Georgia West (SGW) SSMU and 4% to the South Georgia East (SGE) SSMU following the distribution of colonies reported by Trathan et al. (1998). Fur seal consumption for South Georgia was taken from Boyd (2002a); 99% was apportioned to the SGW SSMU and 1% to the SGE SSMU following the distribution of breeding sites reported by Boyd (1993).

Estimates of consumption by pelagic predators were limited to those of baleen whales and fish; consumption by crabeater seals and squid was not included. Estimates of baleen whale consumption were taken from Reilly et al. (in press) who reported the results of a marine mammal survey conducted across the Scotia Sea as part of the CCAMLR-2000 Survey. Of the estimated consumption in the Antarctic Peninsula stratum, 50% was apportioned to the Antarctic Peninsula Pelagic Area (APPA) SSMU and 50% was divided among the seven non-pelagic SSMUs bounding the Antarctic Peninsula in proportion to their area. Of the estimated consumption in the Scotia Sea stratum, 25% was apportioned to the South Orkney Pelagic Area (SOPA) SSMU and 25% to the South Georgia Pelagic Area (SGPA) SSMU. The remaining 50% was divided among the five non-pelagic South Orkney and South Georgia SSMUs in proportion to their area. Estimates of fish consumption were taken from Kock (1985) using the highest numbers in his Table 6 for South Georgia, South Orkney Islands and Elephant Island–South Shetland Islands combined. Fish consumption was divided among the non-pelagic SSMUs in proportion to their area. Consumption estimates are summarised in Table 2.

Estimates of the standing stock of krill were taken from the results of the CCAMLR-2000 Survey. Krill biomass densities for the non-pelagic SSMUs near South Georgia, the South Orkney Islands and the South Shetland Islands were set as being equal to the densities estimated for the three CCAMLR-2000 Survey strata corresponding to these areas. Krill biomass density for the APPA SSMU was set as being equal to the estimated density for the Antarctic Peninsula stratum, and krill biomass densities for the SOPA SSMU and SGPA SSMU were set as being equal to the estimated density for the Scotia Sea stratum. Assumed krill biomass densities for each SSMU are listed in Table 1.

Predator indices of early-season availability of krill were derived from observations in the South Georgia and the South Shetland areas, the only places where concurrent estimates of krill biomass and predator performance are available. For South Georgia, the arrival weight of male macaroni penguins (CEMP index A1) and the average duration of the first six foraging trips of lactating

Table 2: Annual predator demand for krill estimated for major consumer groups in each SSMU in Subareas 48.1, 48.2 and 48.3, expressed in thousands of tonnes.

SSMU	Fur Seals	Penguins	Whales	Fish	Σd_{ij}
Antarctic Peninsula Pelagic Area (APPA)	0.0	0.0	549.5	0.0	549.5
Antarctic Peninsula West (APW)	0.0	193.9	92.8	116.3	402.9
Drake Passage West (APDPW)	3.3	83.5	39.9	50.1	176.7
Drake Passage East (APDPE)	0.1	86.6	41.5	52.0	180.1
Bransfield Strait West (APBSW)	0.0	116.2	55.6	69.7	241.5
Bransfield Strait East (APBSE)	0.0	151.6	72.5	91.0	315.1
Elephant Island (APEI)	0.3	191.2	91.5	114.7	397.7
Antarctic Peninsula East (APE)	0.0	0.0	155.7	195.2	350.9
South Orkney Pelagic Area (SOPA)	0.0	0.0	315.4	0.0	315.4
South Orkney West (SOW)	0.0	21.1	72.3	493.6	587.1
South Orkney North East (SONE)	0.0	28.2	48.5	331.1	407.9
South Orkney South East (SOSE)	0.0	239.8	69.6	475.2	784.7
South Georgia Pelagic Area (SGPA)	0.0	0.0	315.4	0.0	315.4
South Georgia West (SGW)	696.0	7756.8	192.3	425.8	9070.9
South Georgia East (SGE)	7.0	323.2	248.0	549.2	1127.4

Table 3: Predator indices and acoustic estimates of krill biomass density sampled in the vicinity of South Georgia and the South Shetland Islands. A1 is the weight in grams; A2 is the log of the duration of the first incubation shift in hours; C1 is –1 x the log of the average of the first six foraging trips in hours. Note that the estimate of krill density for 1999/2000 in the South Shetland Islands was taken from the time series of standard surveys conducted by the US AMLR Program and differs from the CCAMLR-2000 Survey estimate for the South Shetland Islands stratum obtained in January 2000 (25.7 g m^{-2} versus 37.7 g m^{-2}). The CEMP and krill survey data are listed here with permission from the data collectors.

Year	South Georgia			South Shetland Islands		
	Krill (g m^{-2})	A1	C1	Krill (g m^{-2})	A2	C1
1987/88	no data	no data	no data	41.6	2.514	–4.441
1988/89	45.1	5357	no data	82.4	2.491	no data
1989/90	45.1	5344	–4.364	17.1	2.592	–4.526
1990/91	6.4	4939	–5.312	23.8	2.425	–4.745
1991/92	95.0	5465	–4.572	38.0	2.452	–4.559
1992/93	65.8	5278	–4.813	1.2	2.420	–4.674
1993/94	7.4	5285	–6.150	3.1	2.301	–4.636
1994/95	no data	5185	–4.631	7.5	2.271	–4.499
1995/96	26.7	5314	–4.496	26.8	2.369	no data
1996/97	25.2	5210	–4.578	50.0	2.428	no data
1997/98	21.4	5131	–5.047	60.2	2.548	–4.611
1998/99	12.0	5420	–4.747	14.8	2.415	–4.716
1999/2000	12.3	5090	–4.651	25.7	2.272	–4.422
2000/01	34.7	5263	–4.701	6.6	2.320	–4.176
2001/02	46.6	5240	–4.628	3.3	2.451	–4.331
2002/03	no data	no data	no data	24.5	2.272	–5.136

fur seals (CEMP index C1) were compared with acoustic estimates of krill biomass density from Brierley et al. (1999) and unpublished data held by the British Antarctic Survey. For the South Shetland Islands, data on arrival weight are not available. Instead, the duration of the first incubation shift for Adélie penguins at Admiralty Bay (CEMP index A2) and CEMP index C1 at Seal Island and Cape Shirreff were compared with acoustic estimates of krill biomass density from Hewitt and Demer (1994), Hewitt et al. (2003) and unpublished data held by the US Southwest Fisheries Science Center. These datasets are listed in Table 3.

Results

Estimates of a_i and Y_i for each SSMU based on each of the five options described above are presented in Table 4. Sixty-six percent of the historical krill harvest was taken from three SSMUs (APDPW, SOW and SGE). Accordingly, under option (i) two-thirds of the precautionary catch limit would be apportioned to these SSMUs. Sixty-five percent of the estimated predator demand is concentrated in the SGW and SGE SSMUs, and under option (ii) an equal proportion of the catch limit would be allocated to these SSMUs. Most of the standing stock of krill was mapped in the three pelagic SSMUs during the CCAMLR-2000 Survey and under option (iii), 72% of the catch limit would be apportioned to these SSMUs. Under option (iv) an even greater proportion of the precautionary catch limit (80%) would be apportioned to the three pelagic SSMUs.

Development of option (v) requires examination of the data listed in Table 3. The predator and krill data for South Georgia describe response functions (Figure 2) similar to those described for combined indices of predator performance at South Georgia (Boyd and Murray, 2001; Boyd, 2002b). In contrast, the predator and krill data for the South Shetland Islands are more scattered (Figure 3). This is not surprising given that the ratio of predator demand to standing stock of krill at South Georgia is several times higher than that at the South Shetland Islands (Everson and de la Mare, 1996; Trathan et al., 1995; Boyd, 2002b) and that reproductive failures among krill predator populations have been associated with low levels of krill availability at South Georgia (Brierley et al., 1999; Croxall et al., 1999; Boyd and Murray, 2001). It is possible that stronger relationships between predator performance and krill density may be demonstrated as more of the South Shetland Islands data are explored, but, from the limited number of indices considered here, it appears that land-based predators at South Georgia are more sensitive to changes in krill availability during the early summer than similar predators in the South Shetland Islands. It is interesting to note that the fur seal data (displaying no apparent relationship to krill density) were collected from colonies located in the APEI and APDPW SSMUs, while the penguin data (displaying a weak relationship with krill density) were collected from colonies located in the APBSE SSMU.

Given the apparent relationships in Figures 2 and 3, and considering option (v), the precautionary catch limit in the two South Georgia SSMUs and the two Bransfield Strait SSMUs could vary from year to year depending on the value of a predator index which would be measured near the beginning of the CCAMLR fishing season (1 December). The value of a_i for these SSMUs could follow the form of the example response functions shown in Figures 2 and 3. Alternatively, the value of a_i could be determined by a threshold value of the predator index. If that index falls below some threshold, the SSMUs could be closed to fishing (i.e. $a_i = 0$), otherwise the full allocation could be taken. For the purpose of illustration, option (v) was developed using initial estimates of a_i and Y_i based on standing stock less predator demand (option (iv)). The subdivision of the precautionary catch limit among the other SSMUs would remain fixed. The catch limit in the SGW SSMU would be zero because demand exceeds standing stock; only the catch limits in the SGE, APBSE and APBSW SSMUs would vary as indicated in Table 4.

Discussion

Improvements to the options presented here are possible. The addition of estimates for squid and crabeater seal demand for krill would be likely to result in larger proportions of the catch limit being allocated to the non-pelagic SSMUs under option (ii), as well as options (iv) and (v). Non-breeding fur seals and breeding male fur seals were excluded because of the lack of information regarding their feeding ecology (Croll and Tershy, 1998). Nevertheless, substantial numbers of sub-adult male fur seals are found in the vicinity of all the islands during the summer months and their inclusion would substantially alter the estimates of predator demand. Their inclusion would tend to offset the effect of including squid and crabeater seal consumption. The information used to estimate krill consumption by fishes is dated and could be improved by incorporating information from more contemporary surveys. The use of a single estimate of standing stock (i.e. the CCAMLR-2000 Survey) assumes that the geographic distribution of krill biomass during the survey was representative of the distribution during any year.

Table 4: Subdivision of precautionary catch limit for krill in Subareas 48.1, 48.2 and 48.3 by SSMU using five different options.

SSMU	Option (i) Historical Catches		Option (ii) Predator Demand		Option (iii) Standing Stock		Option (iv) Standing Stock – Predator Demand		Option (v) Adjustable	
	a_i	Ya_i (10^3 tonnes)	a_i	Ya_i (10^3 tonnes)	a_i	Ya_i (10^3 tonnes)	a_i	Ya_i (10^3 tonnes)	a_i	Ya_i (10^3 tonnes)
Antarctic Peninsula Pelagic Area (APPA)	0.0258	82	0.0361	114	0.0816	259	0.0831	263	0.0831	263
Antarctic Peninsula West (APW)	0.0075	24	0.0265	84	0.0208	66	0.0168	53	0.0168	58
Drake Passage West (APDPW)	0.2316	734	0.0116	37	0.0090	28	0.0072	23	0.0072	15
Drake Passage East (APDPE)	0.1049	333	0.0118	38	0.0093	30	0.0075	24	0.0075	16
Bransfield Strait West (APBSW)	0.0117	37	0.0159	50	0.0125	40	0.0100	32	0.0000–0.0100	0–32
Bransfield Strait East (APBSE)	0.0061	19	0.0207	66	0.0163	52	0.0131	42	0.0000–0.0131	0–42
Elephant Island (APEI)	0.0965	306	0.0261	83	0.0206	65	0.0165	52	0.0165	57
Antarctic Peninsula East (APE)	0.0000	0	0.0231	73	0.0350	111	0.0337	107	0.0337	116
South Orkney Pelagic Area (SOPA)	0.0064	20	0.0207	66	0.2985	946	0.3331	1056	0.3331	1056
South Orkney West (SOW)	0.2211	701	0.0386	122	0.0365	116	0.0313	99	0.0313	100
South Orkney North East (SONE)	0.0161	51	0.0268	85	0.0245	78	0.0208	66	0.0208	56
South Orkney South East (SOSE)	0.0199	63	0.0515	163	0.0351	111	0.0264	84	0.0264	83
South Georgia Pelagic Area (SGPA)	0.0080	25	0.0207	66	0.3423	1085	0.3827	1213	0.3827	1213
South Georgia West (SGW)	0.0320	101	0.5959	1889	0.0253	80	0.0000	0	0.0000	0
South Georgia East (SGE)	0.2124	673	0.0741	235	0.0327	104	0.0178	56	0.0000–0.0178	0–56
Total	1.0000	3170	1.0000	3170	1.0000	3170	1.0000	3170	0.9338–1.0000	3040–3170

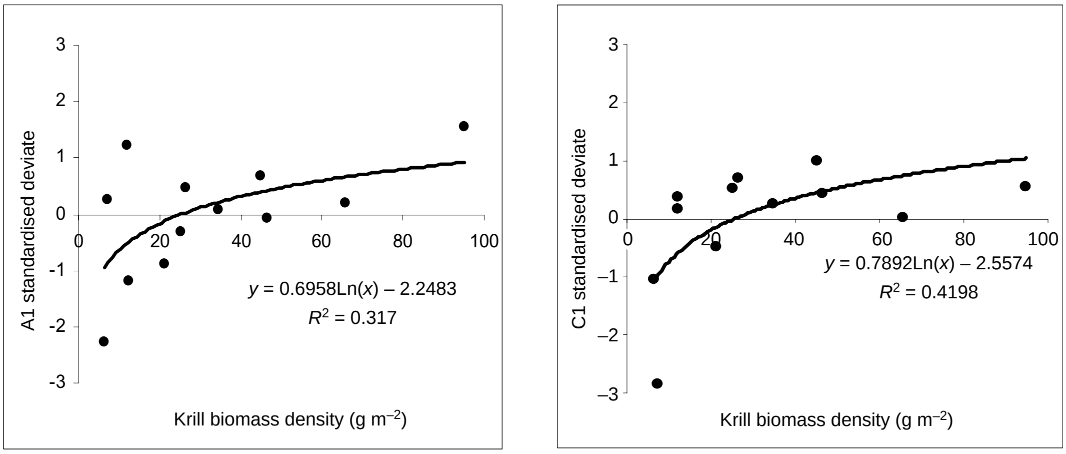

Figure 2: CEMP indices A1 and C1 versus krill biomass density at South Georgia.

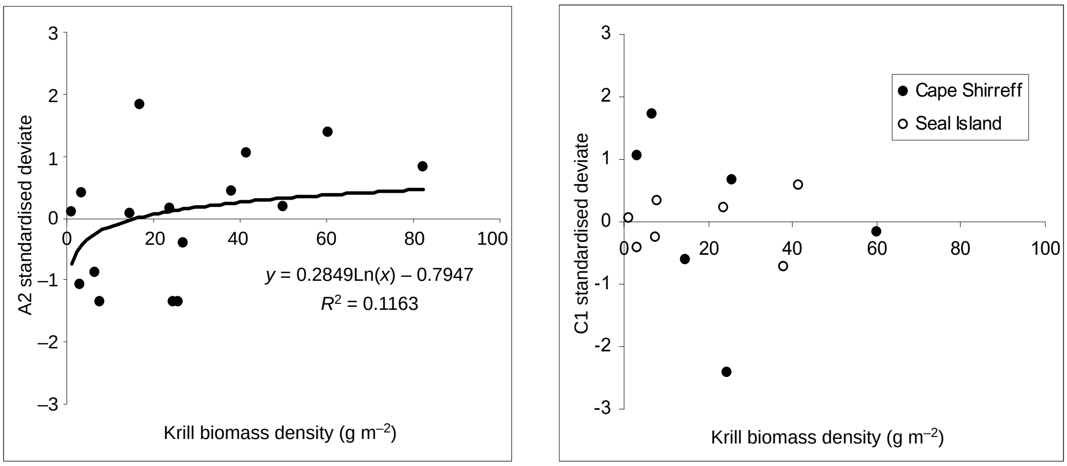

Figure 3: CEMP indices A2 and C1 versus krill biomass density at the South Shetland Islands.

In addition, no consideration was given to seasonal variations in predator demand. In this regard, it is recognised that the traditional fishing season at South Georgia is in winter, and that a predator index from the end of the previous breeding season may be more appropriate for option (v). Nevertheless, CEMP indices A1 and C1 were used as a demonstration of possible methods. Similarly, predator demand and the standing stock of krill were assumed to be evenly distributed among SSMUs within a region. Adding temporal and spatial detail would improve the subdivision of catch among the SSMUs as well as guiding the location of land-based monitoring sites and ship-based krill surveys, which would be required under option (v).

It is important to emphasise that significant relationships may exist between predator response and krill density in other SSMUs. This study focused on four SSMUs (APBSE, APBSW, SGW and SGE) because the data for these areas are available. It may be argued that certain SSMUs remain closed to fishing until monitoring is established. Similarly, it may be argued that allocating a substantial portion of the precautionary catch limit to pelagic SSMUs may be problematic because the harvest would potentially impact on a part of the ecosystem that CCAMLR does not monitor routinely (e.g. pelagic krill predators such as baleen whales, crabeater seals and squid).

Other options and hybrid schemes are also possible. Another option for a static allocation could be based on the difference between the area of an SSMU and that portion of the SSMU where land-based predators are likely to forage. Information required to develop this option would build on that used to define the SSMUs at the workshop held during the 2002 meeting of WG-EMM (SC-CAMLR, 2002). Under this option, more of the catch limit would be allocated to SSMUs with larger differences. Another option for a dynamic allocation could be based on a forecast of krill biomass density in each SSMU from an appropriate population model that integrates data from surveys (e.g. biomass and demographic data) as well as known relationships to the physical environment (e.g. ice and advection). More of the catch limit could be allocated to SSMUs with larger forecasted biomasses. Implementation of this option could include using the forecast to obtain an initial allocation and utilising predator monitoring to fine-tune allocations during the fishing season.

The options presented here are intended to stimulate discussion, and should not be considered definitive proposals. Additional data would certainly improve the calculations presented here. However, it is assumed that more data would not substantially change the following qualitative conclusions:

(i) Approximately 66% of the historical krill catch has been taken in three SSMUs adjacent to Livingston Island (part of the South Shetland archipelago), Coronation Island (part of the South Orkney archipelago) and the eastern end of South Georgia. Under option (i) a correspondingly high proportion of the catch limit would also be concentrated in these areas.

(ii) Approximately 67% of the total demand for krill by land-based predators in the Scotia Sea is in the vicinity of South Georgia. Under option (ii) a correspondingly high proportion of the catch limit would also be concentrated in this area.

(iii) The subdivision of the catch limit among SSMUs using option (iii) is more conservative with respect to land-based predators. Under this option approximately 72% of the catch limit would be allocated to the pelagic SSMUs, but such an allocation would concentrate fishing in areas where monitoring effort is limited.

(iv) The proportion of the catch allocated to pelagic SSMUs would increase to approximately 80% using option (iv), and no catch would be allowed in the SGW SSMU. Despite an increased allocation to pelagic SSMUs, variations in krill availability may still result in intense competition between natural predators and krill trawlers with both options (iii) and (iv). This may be illustrated by considering the range of estimated krill biomass densities in the South Shetland Islands (Table 3). Assuming predator consumption is constant over time, demand would exceed standing stock in the non-pelagic SSMUs during at least one-third of the years. This would not, however, affect the allocation of catch to non-pelagic SSMUs, as the allocation is static, based on single estimates of predator demand and standing stock.

(v) One approach to addressing the latter problem is an adjustable catch limit. Option (v) was developed as an example of such an approach by making the allocation proportional to indices of predator performance that were measured early in the fishing season. Because of the uncertainties linking predator performance to krill availability, it may be preferable to use an index of krill abundance (from ship-based surveys) and/or an index of krill transport into an SSMU. However, procedures for doing so will need to be defined, accepted and implemented. In contrast, procedures for monitoring land-based predators are in place, and data on predator performance are currently being collected.

The implications of the various options, with respect to the operation of the fishery and the terms of the Convention, may also be discussed in general terms:

(i) Under option (i), there would be little impact on the existing fishery or on an expansion of the fishery in the future, as the fleets would continue to use the traditional fishing grounds. As noted above, three of the SSMUs account for two-thirds of the current catch and another three adjacent SSMUs bring the proportion up to 90%. Under this option, the future expansion of the fishery would not change this concentration. Land-based predator populations in these SSMUs are also very large, and the consequences of allowing substantial catches in the vicinity of their breeding colonies could be profound. Furthermore, the possibility of detecting significant change in the predator populations breeding in these SSMUs is limited because CEMP monitoring sites currently exist at only two of the SSMUs (APDPW and SGW). Under this option the potential to contravene the terms of the Convention with respect to maintaining ecosystem relationships is not quantifiable, but likely.

(ii) Under option (ii), there would be little impact on the existing fishery, but as catches increased, fishing fleets would be required to shift their operation to areas that are currently underutilised. Some of these areas may be operationally less desirable for fishing and/or may have the potential for increased by-catch. Under this option the future allowable catch would be relatively evenly distributed among most of the non-pelagic SSMUs. However, three SSMUs (SOSE, SGW and SGE) would account for substantially more, particularly the South Georgia SSMUs. For example, the future allowable catch from SGW would be 15 times greater than the current total catch for all of Area 48. At South Georgia the fishery operates during the winter period when the dominant land-based predators are assumed to have left the area. However, in some years the number of fur seals wintering close to South Georgia can be substantial (British Antarctic Survey, unpublished data). Under this option the potential to contravene the terms of the Convention is not quantifiable, but likely.

(iii) Under option (iii), there would be little impact on the existing fishery, but as catches increased, a major shift in operations would be required. This would involve moving effort to areas that are currently underutilised, predominately pelagic areas that are known to be operationally less desirable for fishing. This implies that if the fishery were to expand substantially, more sophisticated search methods would have to be developed in order to locate fishable aggregations in the open ocean. The pelagic SSMUs were delineated so as to be beyond the foraging range of the majority of the land-based predators, whose reliance on these areas is therefore likely to be small, especially during the periods when they are constrained to return to land in order to provision their offspring. In contrast, little is known about how pelagic predators use the open ocean or about their reliance on the pelagic SSMUs. However, such predators are not constrained to forage from a central place and it is plausible that the impact of the fishery could be relatively minor. Under this option the potential to contravene the terms of the Convention is not quantifiable, but probably small.

(iv) Under option (iv), there would be little impact on the existing fishery, but as catches increased, a major shift in operations similar to those described above for option (iii) would be required. Furthermore, the SGW SSMU would be closed to fishing because estimated predator demand exceeds estimated standing stock. Interference between the fishery and krill predators may be expected to be similar, or less, to that under option (iii), and the potential to contravene the terms of the Convention is not quantifiable, but probably small.

(v) Under option (v), there would be little impact on the existing fishery, but as catches increased, a major shift in operations similar to those described above for option (iii) would be required. As with option (iv), the SGW SSMU would be closed to fishing because estimated predator demand exceeds the estimated standing stock. In addition, the fishery may have to shift its operations on an annual basis in response to early-season indices of krill availability. Estimation errors in the functional response of a predator to krill availability will be likely to have minimal impact, as most of the increase in krill catches would occur in the pelagic SSMUs. In addition, adjustments could be made to the allocation of catch among SSMUs if monitoring reduced or enhanced krill availability. Under this option, the potential to contravene the terms of the Convention is not quantifiable, but probably the least of all the options considered here.

Regardless of how CCAMLR ultimately decides to subdivide the precautionary catch limit of krill in Area 48 among the SSMUs, more immediate information from the fishing fleets will be required in order to ensure that the catches are distributed according to the design. The Scientific Committee recognised this when it specified that the submission of haul-by-haul data by 10-day period should be required when the precautionary catch limit is subdivided among SSMUs (SC-CAMLR, 2002). In addition, an enhanced ecosystem monitoring program will be required so as to ensure that changes in key elements of the ecosystem are detected in a timely manner. Ideally, some form of monitoring should be established in each of the SSMUs. Only with an adequately designed and implemented ecosystem monitoring system will it be possible to separate the causes of ecosystem change between the fishery and the environment (SC-CAMLR, 2003).

Conclusions

Five options for subdividing the precautionary catch limit of krill in the Scotia Sea among SSMUs are presented. Four of the options are fixed allocations; that is, the precautionary catch limit in a given SSMU would not change from year to year, unless new information pertaining to how the initial allocation was made became available. The other option is a dynamic allocation; that is, the precautionary catch limit in a given SSMU would be adjusted each year as a function of an index of krill availability obtained just prior to, or early in, the fishing season. Under all five options there would be little effect on the existing fishery. However, as catches increase a trade-off may have to be made between options that displace the fishery from its current operating area, but reduce the potential for contravening the terms of the Convention, and options that do not displace the fishery, but are likely to contravene the terms of the Convention.

References

Boyd, I.L. 1993. Pup production and distribution of breeding Antarctic fur seals (*Arctocephalus gazella*) at South Georgia. *Ant. Sci.,* 5 (1): 17–24.

Boyd, I.L. 2002a. Estimating food consumption of marine predators: Antarctic fur seals and macaroni penguins. *J. Appl. Ecol.,* 39 (1): 103–119.

Boyd, I.L. 2002b. Integrated environment–prey–predator interactions off South Georgia: implications for management of fisheries. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 12 (1): 119–126.

Boyd, I.L. and A.W.A. Murray. 2001. Monitoring a marine ecosystem using responses of upper trophic level predators. *J. Anim. Ecol.,* 70 (5): 747–760.

Brierley, A.S., D.A. Demer, J.L. Watkins and R.P. Hewitt. 1999. Concordance of interannual fluctuations in acoustically estimated densities of Antarctic krill around South Georgia and Elephant Island: biological evidence of same-year teleconnections across the Scotia Sea. *Mar. Biol.,* 134 (4): 675–681.

CCAMLR. 2000. *Report of the Nineteenth Meeting of the Commission (CCAMLR-XIX)*. CCAMLR, Hobart, Australia: 239 pp.

CCAMLR. 2001. *Report of the Twentieth Meeting of the Commission (CCAMLR-XX)*. CCAMLR, Hobart, Australia: 186 pp.

CCAMLR. 2002. *Report of the Twenty-first Meeting of the Commission (CCAMLR-XXI)*. CCAMLR, Hobart, Australia: 205 pp.

Constable, A.J. and S. Nicol. 2002. Defining smaller-scale management units to further develop the ecosystem approach in managing large-scale pelagic krill fisheries in Antarctica. *CCAMLR Science*, 9: 117–131.

Croll, D.A. and B.R. Tershy. 1998. Penguins, fur seals, and fishing: prey requirements and potential competition in the South Shetland Islands, Antarctica. *Polar Biol.,* 19 (6): 365–374.

Croxall, J.P., K. Reid and P.A. Prince. 1999. Diet, provisioning and productivity responses of marine predators to differences in availability of Antarctic krill. *Mar. Ecol. Prog. Ser.,* 177: 115–131.

Everson, I. and W.K. de la Mare. 1996. Some thoughts on precautionary measures for the krill fishery. *CCAMLR Science*, 3: 1–11.

Goebel, M.E., V.I. Vallejos, W.Z. Trivelpiece, R.S. Holt and J. Acevedo. 2003. Antarctic fur seal pup production in the South Shetland Islands. In: Lipsky, J.D. (Ed.). *AMLR 2001/2002 Field Season Report: Objectives, Accomplishments and Tentative Conclusions*. NOAA Technical Memorandum, NOAA-TM-NMFS-SWFSC-350: 139–152.

Hewitt, R.P. and D.A. Demer. 1994. Acoustic estimates of krill biomass in the Elephant Island area: 1981–1993. *CCAMLR Science,* 1: 1–5.

Hewitt, R.P., J.L. Watkins, M. Naganobu, P. Tshernyshkov, A.S. Brierley, D.A. Demer, S. Kasatkina, Y. Takao, C. Goss, A. Malyshko, M.A. Brandon, S. Kawaguchi, V. Siegel, P.N. Trathan, J.H. Emery, I. Everson and D.G.M. Miller. 2002. Setting a precautionary catch limit for Antarctic krill. *Oceanography,* 15 (3): 26–33.

Hewitt, R.P., D.A. Demer and J.H. Emery. 2003. An eight-year cycle in krill biomass density inferred from acoustic surveys conducted in the vicinity of the South Shetland Island during the austral summers of 1991/92 through 2001/02. *Aquatic Living Resources,* 16 (3): 205–213.

Kock, K.-H. 1985. Krill consumption by Antarctic notothenioid fish. In: Siegfried, W.R., P.R. Condy and R.M. Laws (Eds). *Antarctic Nutrient Cycles and Food Webs*. Springer-Verlag, Berlin Heidelberg: 437–444.

Reilly, S., S. Hedley, J. Borberg, R. Hewitt, D. Thiele, J. Watkins and M. Naganobu. In press. Biomass and energy transfer to baleen whales in the South Atlantic sector of the Antarctic. *Deep-Sea Res., II: Topical Studies in Oceanography*.

SC-CAMLR. 2000. *Report of the Nineteenth Meeting of the Scientific Committee (SC-CAMLR-XIX)*. CCAMLR, Hobart, Australia: 518 pp.

SC-CAMLR. 2001. *Report of the Twentieth Meeting of the Scientific Committee (SC-CAMLR-XX)*. CCAMLR, Hobart, Australia: 577 pp.

SC-CAMLR. 2002. *Report of the Twenty-first Meeting of the Scientific Committee (SC-CAMLR-XXI)*. CCAMLR, Hobart, Australia: 524 pp.

SC-CAMLR. 2003. Report of the CEMP Review Workshop. In: *Report of the Twenty-second Meeting of the Scientific Committee (SC-CAMLR-XXII)*, Annex 4, Appendix D. CCAMLR, Hobart, Australia: 227–282 pp.

Trathan, P.N., I. Everson, D.G.M. Miller, J.L. Watkins and E.J. Murphy. 1995. Krill biomass in the Atlantic. *Nature*, 373 (6511): 201–202.

Trathan, P.N., E.J. Murphy, J.P. Croxall and I. Everson. 1998. Use of at-sea distribution data to derive potential foraging ranges of macaroni penguins during the breeding season. *Mar. Ecol. Progr. Ser.*, 169: 263–275.

Watters, G. and R.P. Hewitt. 1992. Alternative methods for determining subarea or local area catch limits for krill in Statistical Area 48. In: *Selected Scientific Papers, 1992 (SC-CAMLR-SSP/9)*. CCAMLR, Hobart, Australia: 237–249.

Woehler, E.J. (Compiler). 1993. *The Distribution and Abundance of Antarctic and Sub-Antarctic Penguins*. Scientific Committee on Antarctic Research (SCAR), Cambridge: 76 pp.

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Tableau 1: Désignation, zone (A_i), densité de la biomasse de krill (ρ_i) et capture cumulée (C_i) (1988–2002) pour chacune des SSMU adoptées par la CCAMLR en 2002. Les estimations de la densité de la biomasse de krill (ρ) sont tirées des résultats de la campagne d'évaluation CCAMLR-2000 ainsi qu'il est mentionné dans le texte. Les données de capture sont regroupées à partir des soumissions au secrétariat de la CCAMLR. Elles sont ici utilisées avec l'autorisation des personnes qui ont soumis ces données.

Tableau 2: Besoins annuels en krill des prédateurs estimés pour les principaux groupes de consommateurs de chaque SSMU des sous-zones 48.1, 48.2 et 48.3, exprimés en milliers de tonnes.

Tableau 3: Indices des prédateurs et estimations acoustiques de la densité de la biomasse de krill échantillonnés autour de la Géorgie du Sud et des îles Shetland du Sud. A1 est le poids en g; A2 est le logarithme de la durée du premier tour d'incubation en heures; C1 est –1 x le logarithme de la moyenne des six premières sorties alimentaires en heures. Il convient de noter que l'estimation de la densité de krill de 1999/2000 dans les îles Shetland du Sud est tirée de la série chronologique des campagnes d'évaluation standard menées par le programme US AMLR et qu'elle diffère de celle de la campagne CCAMLR-2000 pour la strate des îles Shetland du Sud obtenue en janvier 2000 (25,7 g m^{-2} contre 37,7 g m^{-2}). Les données du CEMP et les données des campagnes d'évaluation du krill sont données ici avec la permission des personnes qui les ont collectées.

Tableau 4: Subdivision de la limite de capture de précaution de krill des sous-zones 48.1, 48.2 et 48.3 par SSMU selon cinq méthodes différentes.

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des Orcades du Sud (SOW); (11) Nord-est des Orcades du Sud (SONE); (12) Sud-est des Orcades du Sud (SOSE); (13) Zone pélagique de la Géorgie du Sud (SGPA); (14) Ouest de la Géorgie du Sud (SGW); (15) Est de la Géorgie du Sud (SGE). Il est à noter que la SSRU APE s'étend en partie dans la sous-zone 48.5.

Figure 2: Indices A1 et C1 du CEMP par rapport à la densité de la biomasse de krill en Géorgie du Sud.

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Табл. 1: Название, площадь (A_i), плотность биомассы криля (ρ_i) и суммарный вылов (C_i) (1988–2002) по каждому из SSMU, принятых АНТКОМом в 2002 г. Оценки плотности биомассы криля (ρ) получены по результатам съемки АНТКОМ-2000, как описано в тексте. Данные по уловам являются сводкой представленных в Секретариат данных; они используются здесь с разрешения представивших эти данные лиц.

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Табл. 3: Индексы хищников и акустические оценки плотности биомассы криля около Южной Георгии и Южных Шетландских о-вов. A1 = вес в г; A2 = логарифм продолжительности первой инкубационной смены в часах; C1 = –1 x логарифм среднего для первых шести походов за пищей в часах. Заметьте, что оценка плотности криля за 1999/2000 г. у Южных Шетландских о-вов была получена по временному ряду данных стандартных съемок, проведенных программой США AMLR, и отличается от оценки по съемке АНТКОМ-2000 для района Южных Шетландских о-вов, полученной в январе 2000 г. (соответственно 25.7 г м$^{-2}$ и 37.7 г м$^{-2}$). Данные съемок криля и CEMP приведены с разрешения лиц, собиравших эти данные.

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Рис. 2: Индексы CEMP A1 и C1 в сравнении с плотностью биомассы криля у Южной Георгии.

Рис. 3: Индексы CEMP A2 и C1 в сравнении с плотностью биомассы криля у Южных Шетландских о-вов.

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A2 = logaritmo de la duración del primer turno de incubación (en horas); C1 = –1 x logaritmo del promedio de los primeros seis viajes de alimentación (en horas). Nótese que la estimación de la densidad de kril en 1999/2000 en las islas Shetland del Sur fue obtenida de las series cronológicas de las prospecciones estándar realizadas como parte del programa AMLR de Estados Unidos y difiere de la estimación de la prospección CCAMLR-2000 realizada en el estrato de las islas Shetland del Sur en enero de 2000 (25,7 g m^{-2} comparado con 37,7 g m^{-2}). Los datos del CEMP y de la prospección de kril se presentan con el permiso de quiénes los recopilaron.

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Figura 2: Comparación entre los índices A1 y C1 del CEMP y la densidad de la biomasa de kril en las islas Georgia del Sur.

Figura 3: Comparación entre los índices A2 y C1 del CEMP y la densidad de la biomasa de kril en las islas Shetland del Sur.